FEEDING PREFERENCE AND ADULT SURVIVAL OF *HADRAULE BLAISDELLI* (COLEOPTERA: CIIDAE) ON DIFFERENT HOST FUNGI (POLYPORACEAE)[1]

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ABSTRACT: The mycetophagous ciid beetle *Hadraule blaisdelli* was reared on the sporocarps of four species of polyporoid fungi. There was a pronounced correlation among preference, amount consumed, and adult survival rates on these fungi in this order: *Bjerkandera fumosa, Coriolus versicolor, Ganoderma applanatum,* and *Phellinus everhartii.* Feeding, preference, and survival rates generaly correlate with the hardness of the sporocarp, although other factors may be involved. Adult beetles fed on powdered sporocarps were able to consume more and had better survival rates.

Hadraule blaisdelli (Casey) is one of the smallest species of Ciidae with an average adult length of only 1.5 mm. It inhabits the sporocarps of long-lasting woody shelf fungi (mostly Polyporaceae). Both larvae and adults bore into the spore-fruits and feed on hyphae and spores. Larger aggregations are frequent and 1000 or more adult beetles may exist within a single sporocarp.

The Ciidae in general are obligate mycetophages which will completely riddle a large sporocarp, leaving only a hollow shell, or small broken pieces, which become part of the forest floor debris. Ciids constitute a major force in the eventual destruction of wood-rotting fungus conks (Rehfous 1955, Graves 1960, Matthewman and Pielou 1971, Ackerman and Shenefelt 1973). Rehfous (1955) cited ciids as pioneer species which invade fresh sporocarps. Graves (1960) found Ciidae in all successional stages in fruiting-bodies, and that the abundance of individuals increased with the aging of the sporocarps (Graves 1960). These beetles may constitute a major portion of the consumer biomass of fungus conks (Matthewman and Pielou 1971).

Hadraule blaisdelli was originally described in the genus *Maphoca* by Casey in 1900, later transferred to *Diphyllocis,* and placed in *Hadraule* by Lawrence (1971). This species is distributed in western North America, and, in California, is found in Lower and Upper Sonoran, Transitional, and Boreal Life Zones (Lawrence 1974). *Hadraule blaisdelli* has been collected from more than a dozen species of host fungi; also, it is the only North American ciid known to infest fungus specimens in herbarium

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collections (Lawrence 1971).

Host preference in Ciidae was discussed by Paviour-Smith (1960), Lawrence (1967a, 1967b, 1971, 1973, 1974), and Ackerman and Shenefelt (1973). Feeding preferences have also been studied in other mycetophagous Coleoptera such as *Bolitotherus cornutus* (Panzer) (Liles 1956, Heatwole and Heatwole 1968) and *Tetratoma fungorum* F. (Paviour-Smith 1964, 1965). Paviour-Smith (1960) used the term "headquarters" for the fungus host(s) in which a particular beetle species most commonly breeds and successfully completes its life cycle. Lawrence (1973) discussed these "headquarters" or "host-preference groups" in great detail. *Hadraule blaisdelli* has a broad host range and it is difficult to determine from existing records any preference for a particular group of host fungi (Lawrence 1973).

Lawrence (1973) stated that the old Friesian "form genera" of polyporoid fungi, e.g., *Polyporus, Fomes,* etc., as defined by Overholts (1953) and modified by Lowe and Gilbertson (1961) and others, are too broad to be of great use in insect feeding preference studies. We follow Lawrence (1973) in using a classification based on Donk (1971), Bondarzew and Singer (1941) and others. The names of each fungus species used in this study are listed below followed by the former names in parentheses:

Bjerkandera fumosa (Persoon ex Fries) Karsten (=*Polyporus fumosus*)
Coriolus versicolor (L. ex Fries) Quelet (=*Polyporus versicolor*)
Daedaleopsis confragosa (Bolton ex Fries) Schroeter (=*Daedalea confragosa*)
Ganoderma applanatum (Persoon ex Wallroth) Patouillard (=*Fomes applanatus)*
Phellinus everhartii (Ellis and Galloway) Ames (=*Fomes everhartii)*

MATERIALS AND METHODS

The *H. blaisdelli* used in this study originated with a colony found in a dry specimen of *Daedaleopsis confragosa* which had been collected in Saugatuck, Allegan County, Michigan in March, 1957, by Robert and Anne Graves. There were no obvious signs of insect infestation at the time the fungus specimen was collected, placed in an envelope and sealed. When opened in July, 1970, there were 900-975 *H. blaisdelli* adults and numerous larvae present. We assumed that a few individuals had been in the specimen when collected and had multiplied since. The possibility of a herbarium infestation (Lawrence 1973, 1974) seems highly unlikely but cannot be ruled out, and, if this were the case, the original source of the beetles is unknown. Additional fungi were provided and a stock culture was then developed from the original group. Specimens from this culture were used in all experiments.

Hadraule blaisdelli colonies can survive indefinitely on dry fungi without the addition of water. Apparently they are able to use metabolic water, a prerequisite for a successful herbarium pest. A well-developed cryptonephridial association of the Malpighian tubules with the rectum is present (Klopfenstein 1972).

In feeding preference and survival studies we tried to eliminate certain variables such as differences in texture, shape, size, and compactness of the sporocarp. Fungus samples were first cut into pieces (*P. everhartii* had to be sawed), and then ground by passing through a grinder several times. The remaining powder was placed in plastic boxes (12.7 mm square by 3.175 mm deep), tamped, and moistened with 2-3 drops of water. This dried into compact pellets which could be placed into the culture dishes. Pellets allowed easier viewing of the beetles which are difficult to find in entire sporocarps. Entire pieces were also used in some experiments.

In each experiment the same number of beetles was added to a small vial along with a sample of fungus. Beetles were removed from the stock culture with a fine brush, examined to make sure they were alive (they play dead when disturbed), and placed in the vials. The sexes can only be distinguished on dead, slide-mounted specimens so an equal number of each sex in each vial could not be guaranteed.

A small piece of filter paper was placed in each vial and a drop of water was added every three days. Experiments were done in the dark except for counting and addition of water. The room temperature averaged 23°C with only minor fluctuations.

It should be stressed that these studies were done with adult beetles. Larvae are small (a fraction of a mm in early stages), fragile and difficult to handle. They burrow into the fungus samples and it is impossible to find and count them without damage.

RESULTS AND DISCUSSION

In order to determine which fungus species were more conducive to survival of *H. blaisdelli*, 1 g of each species (ground and formed into pellets) was placed in separate Stender dishes. Fifty adult beetles were added to each dish and the survivors were counted after 20 and 30 days. This experiment was done three times, and the average number of survivors is shown in Table 1. Figure 1 shows the average percentage of survivors on each host species. After 20 days, survival was 92% on *B. fumosa*, 83% on *C. versicolor*, and 64% on *G. applanatum* and *P. everhartii*. But after 30 days, the survival on *B. fumosa* was 89.3%, while the beetles survived about half as well on *C. versicolor* (38.6%), and less well on *G. applanatum*

(25.3%) and *P. everhartii* (9.3%). By use of the Kolmogorov-Smirnov goodness of fit test (Zar 1984) it was shown that the differences in survival on these four species were significant beyond 0.001.

As the fungi had been powdered, one might assume that variations in hardness had been eliminated. However, the difficulty in chewing very hard fungi such as *P. everhartii,* even when powdered, may still be a problem for such small beetles. Another important factor is the nutritional value of the fungi (Gilbertson 1984, Martin 1979). *H. blaisdelli* has a relatively enormous gut which fills most of the body cavity and is normally packed with hyphae and spores (Klopfenstein 1972). This indicates that a large volume of food must be consumed in order to obtain adequate nutrition. At room temperature (23°C) 50 adults ate 0.01 g of *B. fumosa* in an 8-day period, or 0.025 mg per beetle per day. The average weight of an adult beetle is 0.134 mg. Therefore the average adult *H. blaisdelli* will consume 18.7% of its weight in *B. fumosa* per day. The beetles survived best on *B. fumosa.* The differences in the quantity of different fungus species eaten by the beetles is statistically significant beyond 0.001 according to ANOVA (analysis of variance) (Zar 1984). While the beetles consumed a greater quantity of all fungus species when the sporocarps were ground, there is still a statistically significant difference (beyond 0.001, ANOVA) between the amounts eaten of each species. On harder and/or less nutritious host species, the beetles may be unable to consume enough and their survival is reduced.

In order to discover if there were differences in the feeding rate with different species of fungi, 50 adult beetles were placed in each of four vials with 1 g of fungus (powdered and formed into pellets) and allowed to remain for 20 days. This experiment was repeated three times. The beetles ingested greatest amounts of *B. fumosa* followed by *C. versicolor, G. applanatum,* and *P. everhartii* (Table 1).

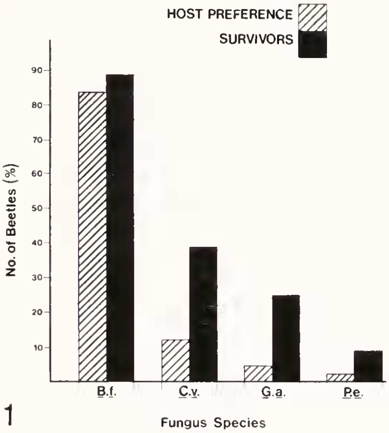
A similar experiment using fungi in the natural state correlated well with the preceding (Table 1). Figure 2 shows the weight of natural fungus consumed compared with that which had been ground. Grinding enabled the beetles to eat more of each species, but the difference is most noticeable in the relatively hard species, *G. applanatum* and *P. everhartii,* in which double or triple the weight was consumed when the fungus was ground. *P. everhartii* has the heaviest and hardest sporocarp of any which were available to us, and, after sawing it, we estimated it to be harder than oak wood. Lawrence (1973) cited only one ciid, *Malacocis brevicollis* (Casey), known to breed in this fungus species. It is apparent that hardness of the sporocarp is at least one factor which may inhibit survival of Ciidae.

In the host preference studies, four small vials (6 mm in diameter) were placed on their sides like spokes of a wheel within a covered petri dish. To each vial the same amount of one of the four fungus species was added. One hundred beetles were placed in the center of the dish. After four days the number of beetles in each vial were counted. This experiment was repeated three times. The numbers of beetles present in each vial were as follows: *B. fumosa* (69, 57, 64), *C. versicolor* (4, 11, 8), *G. applanatum* (2, 5, 3) and *P. everhartii* (1, 0, 3). The average percent of those beetles showing a preference for *B. fumosa* was 84%, *C. versicolor* 10%, *G. applanatum* 4%, and *P. everhartii* 2%. It is obvious that, of the four species of fungi used in these experiments, *H. blaisdelli* preferred these in the order listed above and shown in Figs. 1 and 3. These data are statistically significant beyond 0.05.

From these experiments we can draw the following conclusions. A colony of *Hadraule blaisdelli* survived for years on dry specimens of *Daedaleopsis confragosa.* When given a choice among four other species of fungi, the adult beetles preferred *B. fumosa, C. versicolor, G. applanatum* and *P. everhartii* in the order named, and also ate more of and survived best on these fungi in the same order. The strong correlation among preference, weight of food consumed, and survival is shown by Figs. 1, 3 and 4. It is also obvious that, of the four experimental fungi, *B. fumosa* is far superior to the others as a host. It appears doubtful that *H. blaisdelli* could survive on *P. everhartii* in nature.

Lawrence (1973) discussed the structural characteristics of polyporoid fungi in detail. He divided the North American species into four "host preference groups" with respect to Ciidae. Most ciid species are associated with one of these preference groups, but some, such as *H. blaisdelli* are polyphagous, and no preference group is apparent (Lawrence 1973). The fungi used in our experiments included representatives of three of these four groups: 1) *Coriolus* Group *(Coriolus),* 2) *Hirshioporus* Group (not represented), 3) *Phellinus* Group *(Phellinus),* and 4) *Ganoderma* Group (*Bjerkandera, Daedaleopsis,* and *Ganoderma).*

Our results indicate that, although *H. blaisdelli* is a polyphagous species, there are still pronounced differences in host preferences as well as the ability to feed and survive on the experimental fungi. Hardness of the sporocarp is at least one factor that appears to correlate with these differences. *H. blaisdelli* has not been reported from *Bjerkandera fumosa* in nature but Lawrence (1973, 1974) recorded it from the closely related *B. adusta* (Willd. ex Fries) Karsten (= *Polyporus adustus*). Both *B. adusta* and *B. fumosa* are monomitic and remain relatively soft. Ten other ciid species are known to breed in *B. adusta* (Lawrence 1973). *Coriolus versicolor* is one of the tremetoid group of fungi and is leathery in texture; Lawrence (1973) recorded 16 species of Ciidae breeding in this species. *Daedaleopsis confragosa* has a firm fruiting body with large irregular openings; Lawrence (1973) reported 3 species of ciids breeding in it (one



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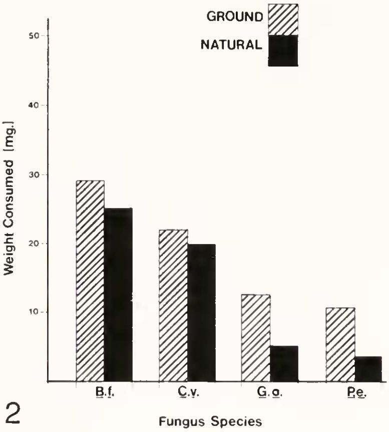

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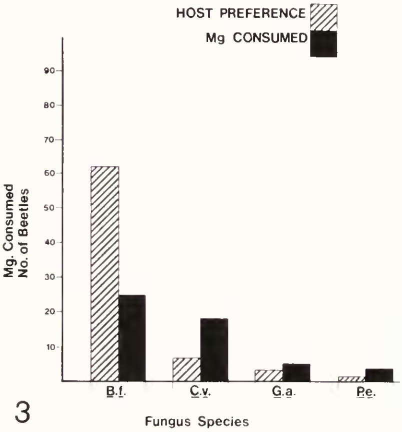

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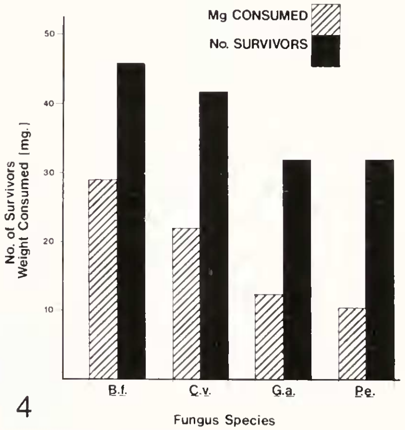

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Fig. 1. Host preference (average percent of beetles showing a preference) compared with survivors (average percent of beetles surviving after 30 days.).

Fig. 2. Average amounts of fungi consumed (mg) by 50 beetles in 20 days. Comparison of amounts eaten using ground fungus and natural fungus.

Fig. 3. Preference (average number of beetles out of 100 found on each fungus species after four days) compared with the average amount (mg) of natural fungus consumed by 50 beetles in 20 days.

Fig. 4. Average amount of ground fungus consumed by 50 beetles in 20 days compared with the average number of survivors (out of 50 beetles) after 20 days.

B.f. - *Bjerkandera fumosa*; C.v. - *Coriolus versicolor*; G.a. - *Ganoderma applanatum*; P.e. - *Phellinus everhartii*.

of which was our *H. blaisdelli* record). It is interesting that Paviour-Smith (1960) noted that "a type of structure appears to be reached in the really tough trimitic fungi (*Daedalea quercina*) where no species even tries to live." *Ganoderma applanatum* is trimitic, hard and tough, and yet 10 species of North American Ciidae are known to breed in this species (Lawrence 1973). *Phellinus everhartii* is dimitic and extremely dense and hard with only one breeding ciid known.

In the polyphagous *H. blaisdelli,* hardness of the sporocarp is an important limiting factor. Hardness correlates generally with preference, feeding, and survival in experiments with four diverse and unrelated genera of fungi. It is interesting that *P. everhartii*, when ground, is consumed in much greater amounts (Fig. 2) and that survival is then comparable to the softer *G. applanatum* (Fig. 4). As these beetles may eat nearly a fifth of their body weight in dry fungus per day, the nutritional value of the host must also play an important part in survival.

Table 1. Survival of and amount of fungus consumed by *Hadraule blaisdelli* on four species of fungi (averages of three experiments using 50 individuals each).

Fungus species	Average number of adults surviving (out of 50)		Average amount of fungus consumed (mg) by 50 adults after 20 days	
	after 20 days	after 30 days	natural	ground
B. fumosa	46.0	44.7	25	29
C. versicolor	41.5	19.3	18	22
G. applanatum	32.0	12.7	5	12.5
P. everhartii	32.0	4.7	3.5	10.5

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